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PRIZE ESSAY

ON

CANALS AND CANAL CONVEYANCE.

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THE

PRIZE ESSAY

ON

Canals and Canal Conveyance.

FOR WHICH

A PREMIUM OF £100 WAS AWARDED

BY THE

CANAL ASSOCIATION.

BY W. O'BRIEN, ESQ.

ENGINEER, ON THE RAILWAY LINE BETWEEN MOSKOW AND THEODOSIA.

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M. C.

"REPORT OF THE COMMITTEE OF THE CANAL ASSOCIATION ON THE ESSAYS SENT IN FOR THE PRIZE.

"In compliance with the instructions of the last Annual Meeting, the Committee have carefully examined the Essays which were sent in, in competition for the Prize, and are prepared to report the result. Before, however, they state the conclusion at which they have arrived, it may be useful to explain the circumstances which led to the offering a Prize, and the steps which were taken to carry out the plan.

"At the 'CANAL COMPANIES' MEETINGS' in 1844-5 which resulted in carrying the Canal Companies' Tolls Act, 8 and 9 Victoria, c. 28, and the Canal Carriers' Act, 8 and 9 Victoria, c. 42,— a scheme was proposed for offering a series of Annual Premiums for Improvements in Canal Works and Management; and it was suggested that the first Prize should be for an Essay on the best method of carrying out the proposed plan, as well as on the general subject of Canals and their management.

"Considerable sums were promised by some of the leading Canals, but unhappily from the want of union, sufficient encouragement was not secured to enable the Committee to carry the scheme into effect. Soon after the formation of the present Association the idea was revived, and the funds at the disposal of the Committee appearing adequate, it was resolved to carry out that part of the original scheme which related to an Essay.

"Accordingly in the month of July last, the following Advertisement was inserted in *The Times*:—

"'CANAL ASSOCIATION.—PRIZE ESSAY ON CANALS.—A Premium of £100 will be given by the Committee of the Canal Association to the Author of the Best Essay on the Present Condition and Future Prospects of Canals and Canal Conveyance, with suggestions as to the Points to which attention, with a view to Improvement, should be principally directed.

"'The Essay must be sent in on or before the Thirty-first December, 1856, to the Honorary Secretary, from whom further particulars may be had on application.

"'THOMAS WILSON, HON. SEC.

"'*Aire and Calder Navigation Office, Leeds, 1st July*, 1856.'

"'And the following observations, in explanation of the views of the Committee, were also prepared and extensively circulated:—

"'The object of the Committee in offering the above Premium is to obtain for those who have the direction and management of Canals such suggestions as may assist them in developing their resources to the utmost possible

extent. It is obvious that for this purpose the Essay should be of an *eminently practical character* and that *a mere Literary* Essay would have no value whatever.

"'Without wishing to prescribe the mode in which the subject should be treated, it may be useful, in the way of suggestion or illustration, to name a few points which would seem to require consideration.

"'The General History of Inland Navigation.

"'The present position of Canals in comparison with other modes of Conveyance—their advantages and disadvantages.

"'Observations on the principal plans which have been proposed for their improvement, and suggestions for further improvement, with an indication of the direction in which the greatest amount of alteration may be expected.

"'The different modes of passing from one level to another—the form and size of Vessel best adapted for slow and quick transit—the best method of propulsion—the cost of maintenance—working expenses—hauling—or towing, and transit generally—both actual and relative—and these in reference both to Broad and Narrow Canals.

"'Tolls—their actual amount and average rate—with the effects of high and low charges.

"'The Parliamentary powers usually granted to Canals, and where they are defective.

"'The various systems of Canal Management—the necessity for united action—the best form of Accounts—the General Statistics of Inland Navigation—and the best method of obtaining and recording from time to time information upon the Construction, Management, and Improvement of Canals and Canal Navigation.

"'The Essay must be sent in to the Honorary Secretary on or before the 31st December, 1856.—It must be sealed up and bear a motto:—and the name and address of the writer must be sent in a sealed Envelope with a corresponding motto. The Envelope belonging to the successful Essay will alone be opened, except in those cases where there may be a request to the contrary.

"'The Committee reserve to themselves the right of printing the successful Essay—in which case, however, they will not seek for any pecuniary advantage.

"'THOMAS WILSON, Hon. Sec.

"'*Aire and Calder Navigation Office, Leeds*, 1st *July*, 1856.'

"It will be seen that it was the aim of these observations, while carefully guarding against dictating or even recommending any particular course, to suggest some of the leading points of interest on which it was desirable to touch, with the special view of giving a practical character to the Essay. That this precaution was essentially necessary was only too obvious when the applications for information were received, it being only apparent that

the majority of the parties were devoid of any special acquaintance with the subject, and proposed to themselves a mere literary compilation instead of a practical Manual.

"It is not impossible that the circulation of this prospectus may have tended somewhat to discourage those who had no special knowledge of Canals from competing for the Prize. Certain it is that when the time arrived for receiving the Essays, only Eleven were sent in; and of these not more than three or four possessed any merit.

"The Committee cannot but express their regret that of those who are actively engaged in the management of Canals, and who from their long experience, as well of the advantages Navigations possess, as of the difficulties they have had to contend with, must be well able to offer the most valuable suggestions for their management and improvement, none have been induced to enter the lists on the present occasion.

"The whole of the Essays were submitted to Mr. Beardmore, C.E., who has carefully examined them and drawn up a very able report on their respective merits. The Committee having previously examined them, entirely concur in the conclusions at which Mr. Beardmore has arrived; and while they agree with him in awarding the Prize to the Author of the Essay marked 'Steam Tug,'—(who was found to be Mr. W. O'Brien, C.E., Champagney, Haute Saône, France,) as on the whole the best; they also concur in his views that those bearing respectively the motto 'Juste Judicato,' and 'Deter Digniori,' 'are superior, the latter in bold originality and suggestion of stronger 'co-operation among Canals; and the former in a remarkably well written 'outline of the difficulties and obstacles attached to the application of Steam 'Power on Canals, as they exist in this country;—but that the one to which 'they award the Prize is a very careful and laborious Essay, and more complete as an entirety than any other.'

"THOMAS WILSON, Hon. Sec."

CHAPTER I.

RUDIMENTS OF THE ART OF CANAL ENGINEERING.

§ 1.

ON THE ESTABLISHMENT OF CANALS.

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Surveys.

INDEPENDENTLY of their size canals can be divided into two categories:—1st, those that join two rivers or valleys; 2d, those that are parallel to rivers and follow the same valley in their course. The latter seldom present any serious difficulty of execution; the former, having to be led through or over high ridges, necessitate a great many locks, deep cuttings, often tunnels and are not easily supplied with water.

The position and direction of a canal, more particularly in the first category, require a careful study, which is greatly facilitated by a good map, such as the Ordnance map of Great Britain.

The following is the manner in which the undulations of the soil are expressed on the Ordnance map:

Suppose it be required to represent a conical hill, as in Fig. 1, vertical sections, such as *a*, *b*, *c*, are constructed by means of proper surveying and levelling instruments. Horizontal sections, 1, 2, 3 . . . . . are then determined at different heights, the vertical distance is obtained by the vertical sections. When the horizontal sections are close one to another the declivity of the ground is rapid (see Fig. 2); where they are concave, there is a depression in the soil; where they are convex there is a summit. The Ordnance map does not give these horizontal curves or sections; they only form a sort of skeleton-work for a series of graduated hatchings; but, in preparing surveys for railway or canal works, it is absolutely necessary to preserve the horizontal curves with the indications (in feet) of their height above the level of the sea or any other given datum. (1)

When two rivers are parallel and run in the same direction, there exists an elevation at the point where they diverge. If they unite, there is a depression at the point where they meet together; if they run in opposite directions, one of the highest points of the

1 The French Ordnance map gives the height of remarkable places above the level of the sea; it is much to be regretted that it is not so with the Ordnance map of Great Britain.

ridge or plateau which separates them, is found by joining by a straight line *i k* the sources of the two rivers. (See Fig. 3.)

These principles, when well understood, serve to determine by a single glance at the map, and with a certain approximation, the position and direction of a canal between two given places, the position of its summit level and that of the reservoirs and feeders.

How to calculate the supply of water.

When the presumed site of a canal is fixed, the next step must be to determine the quantity of water that it will require.

Water is lost through five causes:

1st. The passage of boats through locks;

2ndly. Evaporation;

3rdly. Leakage through the sides and bottom of the canal;

4thly. Leakage of lock-gates, &c.

5thly. Turning water out of the pounds for repairs.

1st. Every one knows that canals are formed of level portions of *pounds* situated at various heights. The manner of ascending or descending from one pound into another by means of locks is so simple that it need not be explained here. The loss of water caused by the passage of a boat through a lock is as follows:

$W = L + B$, when the boat ascends.

W, Loss of water; L, Lockful or prism of water having the area of the lock for its basis and the total fall of the lock for its height; B, volume of water displaced by the boat.

When the boat descends, the loss is $W = L - B$.

A boat going up or down takes W water, whatever be the number of locks, each lockful taken from the summit level going all the way down. If a boat goes up to the summit level and down again on the other side, it causes an expenditure equal to 2 L, supposing the boat's-load not to vary materially in the course of the journey.

If the descending boat is immediately followed by one ascending, or *vice versa*, the loss is still the same, or only L per boat.

Sometimes, in steep ascents, several locks are joined together without any intermediate pound; the cost of construction is lessened thereby; but in that case an ascending boat requires as many locksful as there are locks, in addition to the volume displaced by the boat, or

$$n\,L + B,$$

n being the number of adjacent locks.

In descending, the loss of water is $L - B$ as before.

2ndly. Evaporation. Claudel[1] values the loss of water by evaporation at 3 cubic feet per square yard and per annum; it varies widely from one country to another, and must be found by experiment.

3rdly. Leakage through the sides and bottom of the canal;

[1] Claudel, formules et tables a l'usage de l'Ingénieur.

this varies much and decreases every year; it is generally admitted to be equal to twice the loss from evaporation.

4thly. The quantity of water lost by leakage of lock-gates seldom attains 8 locksful per lock and per annum.

5thly. It only becomes urgent to stop the traffic on canals and empty the pounds when very extensive repairs have to be made. Leaks in the sides are stopped up by throwing sand and clay into the canal, and dredging machines are used for cleaning and deepening the bed.

Most of the water required for navigation has to be derived from the vicinity of the culminating points of canals. For this purpose, the summit level is so disposed as to be lower than the sources of the adjacent water-courses, the water from the latter being turned into the summit level or into a reservoir near to it. (See Fig. 4.) It generally happens that the adjacent streams furnish in summer an inadequate supply of water; it then becomes necessary to establish one or more reservoirs to contain the water, which has fallen in the winter season. It is obvious that the summit level should be as low as possible, so as to obtain a sufficient supply of water and to avoid unnecessary locks. In most cases a cutting or tunnel is necessary; sometimes in making the excavations springs are met with which contribute a considerable quantity of water (1).

The quantity of water that can be obtained at the summit level depends on the extent of the tributary area, the structure of the soil, the absorption of plants and atmospheric conditions.

Claudel admits that in France, a river delivers about $\frac{1}{4}$ of the annual produce of the rain that falls in the area tributary to it.

Lateral canals, which derive their supply from rivers at points considerably below their source are easily fed, offer but few difficulties to the Engineer, and cost little.

In laying out a line, the following conditions should be fulfilled:—

1st. To avoid porous soils;

2ndly. To avoid passing through expensive property, except for the establishment of basins in commercial centres;

3rdly. To provide a sufficient supply of water at all times by means of low levels and deep reservoirs;

4thly. To dispose the line so that excavations shall compensate embankments as nearly as possible;

5thly. To make the line as short as possible, sacrificing, if necessary, some of the preceding conditions, so as to obtain a saving in time and in the working expenses.

1 It must be recollected that reservoirs can only *regulate* and never *furnish* the supply of water.

Dimensions.

Fig. 5 shows how canals were originally executed. Raised towing-paths are made at least on one side, frequently on both sides, with the earth dug out for the bed of the canal. The latter is set out with a slope, which is frequently 1 in 1, but which varies with the nature of the soil. The embankments are set out with a slope of about 1 in 1½. At the level of the surface of the water a narrow ledge is left, on which rushes, &c. are planted to protect the banks from waves or ripples. A drain *c* may be necessary to carry off the leakage.

Fig. 6 shows a modification better suited for steam navigation, at least where space is of consequence.

The shores are vertical. They may be protected from the surge caused by steamers, either by means of a lining of *béton* [1] or by rough stone-work without mortar. The drift soon fills up the joints.

I cannot, in a work of this kind, give rules for the construction of bridges, locks, &c. I shall only give the formula:

1st. For calculating the pressure of water on a lockgate or wall. 2ndly. The quantity of water which can be discharged through a sluice of given dimensions, the head of water being known.

1st. Let A be the width of the lockgate, and H the height of water in the pound behind it, and $W = 62{\cdot}50$ lbs. weight of one cubic foot of water; and suppose the lock be empty: then the total pressure is

$$W \; a \; H.$$

If there be a certain depth of water h in the lock, then the total pressure is . . . . . $W \; a \; (H - h)$.

When the side walls are thrust inwards, it is generally occasioned, while the lock is empty, by water having made its way from the upper pound and through the soil to some place behind the wall, the maximum pressure in this case is calculated as in the preceding; supposing the level of the water behind the wall to be the same as that in the upper pound.

The discharge from a sluice is calculated by the two following formulæ:

$$D = S.V \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

D. Discharge in cubic feet per minute.

S. Area in square feet.

V. Velocity in feet per minute.

$$V = 0{\cdot}625 \sqrt{2 \, g. \, h} \quad \ldots\ldots\ldots\ldots \quad (2)$$

$g = 32{\cdot}17^{ft.}$ = the velocity acquired by a body *in vacuo*, when it has fallen for one second of time.

h = height in feet of water from the surface to the centre of the orifice or sluice.

[1] Concrete formed with gravel and hydraulic mortar.

The dimensions of canals vary according to local considerations, and also according to the notions of Engineers. In England there are two systems of canals; the narrow, with locks 7 feet wide, accessible to boats of 30 to 35 tons; and the broad with locks 14 to 18 feet wide, and accessible to boats of 60 to 120 tons; the latter, however, being built without any regard to speed. In the broad canals, the width at the surface of the water is about 40 feet. The canals in the North West of France are accessible to boats of as much as 500 tons, if built in a certain manner, but few convey more than 200 tons freight. The locks most prevalent are 100 feet long by 18 feet wide, the depth of water being from 5 to 7 feet. A great many North-American canals admit large vessels under sail(1). In the North Holland canal two frigates can pass each other with ease.

The annual cost of a canal is as follows:

Annual expenditure.

1st. Interest at 5 per cent. of capital laid out in works, purchase of land, &c.

2ndly. Wear and tear of locks, gates, sluices, &c.

3rdly. Compensation to mill-owners or others, for loss of water, land temporarily occupied, &c.

4thly. Repairs, direction, management, and general expenses.

The third item is usually of little importance, the extent of land required for a canal varies very little, and the canal owners prefer buying all the property they are likely to want, to holding it on lease. The second and fourth item together ought not to go beyond 5 per cent.

§ 2.

On boats and conveyance.

Calculation of resistance.

A great number of rules have been given for calculating the resistance opposed to the movement of boats on canals; none of them can be relied on; in some cases they only give the relative and not the absolute resistance; in others, they give the absolute resistance, but only for old-fashioned boats which are not likely to be used much longer for traffic on canals. Some notion of the absolute resistance will be obtained from Wood's Practical Treatise on Railroads.

The following formula is from Claudel's work . . . . . .

$$E = k \frac{A V^2}{2 g}$$

E. Effort in *kilogrammes*.

K. Coefficient constant with the same boat.

A. Area of greatest immerged transverse section in *square mètres*.

1 In the United States the locks were built originally in timber, and have been enlarged at a moderate expense, which would not have been the case, if masonry had been employed. (See David Stevenson's Civil Engineering in North America.)

V. Speed in *mètres* per second.

g. 9·81 ^{mètres} = 32·17 $_{a}$.

If we reduce this to English measures, that is pressure in pounds and lengths in feet. we have

$$E = 0{\cdot}80\ K\ AV^2 \quad \ldots\ldots\ldots\ldots \quad (1)$$

K having the same signification as before.

K = 1·10 when the boat is a straight prism of which the length is 5 or 6 times its width.

If we suppose the front or bow of the boat to be formed by two vertical planes A B and B C, Fig. 7, forming a certain angle with the longitudinal axis of the boat, the values of K according to this angle are

Angle of 78° ____ 30° ____ 6° ____ bow semi-circular.

K = 1·05 ____ 0·48 ____ 0·44 ____ 0·57, and with a stern formed by two planes forming an angle of 45° with the boat's keel, these values are:

K = 0·94 ____ 0·37 ____ 0·33 ____ 0·46.

K is stated with some fast American steamers to descend as low as 0·045.

The formula (1) shows that, all other circumstances being the same, the effort of traction increases as the square of the velocities; this appears only to be true up to a certain velocity, beyond which it appears that the boat is raised and displaces less water, so that the value of E increases less rapidly than the square of the velocities. The value of K is greater on a canal than in an unlimited expanse of water: certain experiments tend to show that there is a limit beyond which the diminution of the canal's sectional area does not raise the value of K, but is rather advantageous.

The duty performed by an engine in propelling a boat to a certain distance.

D is expressed by the equation.

D E = 0·80 K AV² D.

But if the work is done by a horse harnessed to a rope which forms an angle *a* with the direction of the boat's movement the equation becomes:

E.D cos. *a* = 0·80 K AV² D,

Part of the horse's power being lost from obliquity of the rope.

Urging horses to a trot in towing boats appears to fatigue them very much, and was only practised for a short time with passenger boats. In France, 2 horses haul a boat with about 100 tons at the rate of about 2 miles an hour. In England, one horse hauls a boat with 20 to 30 tons, at the rate of 2½ miles. In Holland I understand that they go quicker.

Cost of haulage with horses.

The cost of conveyance on canals is as follows:

1st. Hire of horses and driver;

2ndly. Interest of capital laid out in boat at 5 per cent. per annum.

3rdly. Wear and tear of boat, at 5 to 10 per cent. per annum;

4thly. Wages of crew;

5thly. Canal tolls, if the boats are not worked by the canal owners;

6thly. General expenses.

As Chapter 4th contains my views on the improvements applicable to canals, and particularly on the use of steam haulage, I shall only give here the method of determining the power of the engines of a steamer, the dimensions of which are known. *Steam boats—Duty of engines.*

The formula given by Claudel, in French measures, is

$$\frac{F.Y}{75} = \frac{V^3 K. A}{2g}\left(1 + \frac{K. A}{K; A}\right)$$

which gives, in English measures: Horse power, or H. P. = $60. V.^3 K. A\left(1 + \frac{K. A}{K; A}\right)$ . . . . (2) a is the area of one paddle-board, or of two, if two paddles are used, in square feet;

V the boat's speed in feet per minute. K, coefficient, varying from 1 to 1·2. This formula supposes the speed to be uniform.

The coefficients K and K, can be determined approximately by comparison with boats already experimented on. K, may be assumed at 1·1.

If we determine, besides, the speed to be attained, the dimensions of the boat, and the probable depth of immersion; formula 2 will enable us to determine the horse power of the engines.

$$\frac{a\ \pi\ s}{33{,}000} = \text{H. P.} \ldots\ldots\ldots\ldots (3)$$

a, area of cylinder in square inches; π effective pressure of steam on piston in pounds per square inch; s speed of piston, in feet per minute.

The effective pressure is here assumed to be that indicated by the pressure gauge; whereas it is always a little inferior in the cylinders, and varies if expansion is used, as of course it should be.

If a screw is applied instead of paddles, formula 2 is still applicable; if a be equal to the area of the vertical projection of the screw, and v equal to the velocity of the screw in the direction of the boat's movement.

The cost of conveying goods by steam-power on a canal is as follows:

1st. Consumption of coals, oil, hemp, etc.

2d. Interest of capital laid out in boats and machinery

3d. Wear and tear of do.

4th. Wages of engineer and crew

5th. Tolls.

6th. General expenses.

Best form of boats. The shape and dimensions of boats used on canals can only vary within narrow limits. Some of the figures in Plate I. give but an indifferent idea of the present state of art in canal boat building. It was formerly admitted that the lines of vessels should be convex in front, as in Fig. 8; experience has proved that hollow lines are best, as in fig. 9, both for sea and river boats.

In Europe, both river and sea-going vessels are usually built with the stem raking forward; this creates a wave in front of the stem.

The Americans have introduced the fashion of stems running straight up from the surface of the water. (See figs. 10 and 11.)

The form of the stern lines has a great deal to do not only with the steering of vessels, but also with their speed.

Except in sea boats, the form of a boat's lines above the water line is of little consequence; deep keel and great draught of water are necessary for the stability of sea-going boats. River and canal boats require a flat floor and no keel.

It cannot be expected that canal boats should be as fast sailers as river boats; but one should try and copy them as far as is compatible with the requirements of a canal navigation. Fine lines not only give speed, they cause a saving in the cost of propulsion. (1)

CHAPTER II.

Succinct History of Canals. (2)

Canals must have been used at a very early age, if not for navigation, at least for irrigation of land; they appear to have been made in Egypt at a very early period. Some time after they were applied to the cultivation and irrigation of land in Lom-

1 I confess my inability to give really useful rules for gauging vessels; it appears to be a question of elementary mensuration; but there are two practical difficulties which make it difficult to value small quantities; the first is the difficulty of measuring the depth of immersion when the water is not quite smooth, and the 2nd is that the depth of immersion or draft of water is seldom the same at both ends. The average draft not giving the exact volume displaced.

2 See Appendix.

bardy; the first important step taken with a view to apply canals on a large scale to navigation, namely, the invention of locks, is attributed to Leonardo da Vinci, towards the year 1500. Notwithstanding the importance of this invention inland conveyance by means of canals does not seem to have been much used till the year 1612 (1), when a French gentleman, (Pierre Paul Riquet,) presented Louis XIV. with a project for a canal from the Mediterranean to the Bay of Biscay, which was commenced under this gentleman's auspices, and at his expense. The execution of this canal has only been finished within a few years, and even now works are still going on for enlarging it and improving the supply of water; the works are let to a company, entitled Compagnie du Canal du Midi, by which name the canal is now known (2). This appears to have been the first attempt to make canals a general mode of internal communication. The Belgium and Dutch canals were begun before, but not under the same difficulties.

Invention of locks.

Canal du Languedoc.

The Canal de Briare appears soon after the Canal du Languedoc; it was opened in 1642. England was far behind the continent in canal engineering; but when once the Duke de Bridgewater had set the example, the English capitalists set on in right earnest. It is a curious fact, that while on the continent the development of those two great instruments of progress, railroads and canals, was gradual, and can be traced rather to the increasing wants of the country, than to the leading influence of any individual; in England, on the contrary, their development was so rapid as to assume the form of a mania, and that almost entirely owing to a few men, more particularly Brindley, for canals, and G. Stephenson, for railroads.

Brindley.

The French, however, boast of their Brisson, Engineer in chief of the "Ponts and Chaussées," who devoted several years to perfecting some of the most important canal lines in France,[3] more particularly the Northern navigation by St. Quentin and the Oise, the canal parallel to the Somme and those from the Rhône and Marne rivers to the Rhine.

Brisson classified the canals according to the boats in use at his time and wrote a large volume on the subject. I think he ought not to have taken into account the habits of the boat-builders or boat owners. I do not think a canal can be too wide if it can be supplied with water. A blunder evident to all Engineers was committed both in England and in France in giving

1 Some attribute the first idea of this canal, to Francis the first; see Ernest Grangest "Précis historique et statistique des voies navigable de la France et " d'une partiè de la Belgique" from which part of this is extracted.

2 Part of the line of navigation between Bordeaux and Cette consists in a canal parallel to the Garonne, the works of which are let to the Southern Railway Company since 1852.

3 Brisson's Essay on Inland Navigation was published in 1829.

the locks, bridges, viaducts, etc., only just width enough for the passage of one boat, so that any considerable increase in the activity of the traffic or size of the boats will compel the canal-owners to pull them down and rebuild them entirely.

Steamers on canals.

The idea of applying steam power on canals is as old as the application of the steamboat itself: it was tried on the Forth and Clyde canal in 1802, but was abandoned on account of the surge caused by the paddles washing the banks of the canal. In 1812, fresh trials were made, and the banks of the canal protected by a coarse stone pitching. I cannot say when the screw was first applied on canals: it was tried with very good results on the grand canal in 1851(1) Paddle-boats have not been long in use on French and Belgian canals; the screw has only been in use since 1800 or thereabouts on French canals. Passenger boats tracked by post-horses were tried in England and Scotland at the beginning of the 19th century, but were abandoned soon afterwards.

Swift passenger boats.

It must not be forgotten that canals were chiefly executed before railways were even thought of; they were made simply with the view of obtaining a better means of communication, than that afforded by common roads. This explains the enormous value which canal property had in England for some years.

In Belgium canals and railroads both belong to Government; there has been scarcely any struggle between the railway and canal interests. In France the Government owning most of the canals and having advanced large sums of money for the construction of railways, was obliged to divide its solicitude between the canals and railways. In England the two systems led to a long struggle: the canal owners tried altogether to prevent the public from having railways at least for the conveyance of heavy goods. After several violent parliamentary contests, the railway-owners not content with gaining their cause by obtaining an act of concession turned all their efforts to ruin the canal owners by conveying traffic at the lowest rates, frequently at their own loss. Instead of trying to ruin the railway interest in England, the canal owners ought rather to have sought means of satisfying the public wants in such a manner as to induce carriers to adopt the canal rather than the railway. But they had enjoyed for years such a complete monopoly that improvement was thought of too late, and the canals were bought or silenced in many instances by the railway companies.

1 See Murray's Rudimentary Treatise on the Marine Engine.—Appendix.

CHAPTER III.

Present position of Canals.

There are five different modes of conveying goods:

1st. Coasting or maritime navigation;
2ndly. Navigation on rivers;
3rdly. Do. on canals;
4thly. Common roads;
5thly. Railroads.

Canals compared with other modes of conveyance.

Wherever the first mode of conveyance can be adopted *without materially increasing the distance*, and if very great velocity is not required it is and always will be preferred. Allowing for sea risks, it is still the cheapest of all the five, and offers great facilities for loading and unloading, and for stowing goods in the best manner for their preservation. The application of the auxiliary screw system will not, probably, on an average, raise the price of freight considerably, as the increase of working expenses which it causes is compensated by a great saving in time.

Common roads will ere long cease to be applicable except for short distances, or in very rugged and mountainous countries. They certainly offer one advantage; it is that they can be made everywhere, and in some places offer the only mode of conveyance possible.

Railroads are less expensive, but, except at high velocities, are more so than every kind of navigation. The characteristic advantage of railways is the enormous velocities which they allow one to attain.

The resistance on roads and railways is independent of the rate of velocity. [illegible] The resistance to a boat's movement varies as the square of the velocities, and at a speed little exceeding 4 miles an hour, is superior to that on railroads. No limit scarcely can be assigned to the velocity attained on a railway. What advantages does navigation offer to compensate for the loss of such an important one as this? It offers first that of economy; and secondly, that of being able to convey *almost unlimited quantities* in a given

time, for we find in formula I. that the resistance in this case varies but little with the length of the vessel, an increased length having only for effect a slight alteration in the value of K, so that thousands of tons can be conveyed by a single boat at sea, or by a single train of boats on a river or canal, (1) at a moderate expenditure.

Canals chiefly differ from rivers as regards the cost of conveyance, in requiring a greater outlay of capital, and being generally narrow, the motive power is not applied in the most advantageous manner; they are consequently less advantageous as a means of conveyance than rivers, unless the latter have a rapid current, or are much longer on account of windings.

Canals compared in particular with railroads.

The competition between railways and canals is a very serious question; the railway companies trying to absorb all the traffic of heavy goods and run down the canal owners. A glance at the table containing the prices of shares of some of our canals will show the disastrous effects of this competition. It has been seriously considered by the French and Belgian Governments, and has ended in their maintaining and even extending their canals and reducing the tolls.

Having considered these 5 means of communication, it is easy to see that each of them offers special advantages, so that, for many things, it cannot be well replaced by any of the others, it is therefore not reasonable to suppose that one or two of them will absorb and supersede the others. None of them have attained the degree of perfection of which they are capable. If they had the cost of conveyance of goods would not increase their value 4 or 5 fold, as is frequently the case. Coal, worth 7 or 8 shillings a ton at the pit's mouth is worth 20 or 30 at 200 miles distance.

It is argued against canals and in favor of railways,

1st. That the cost of haulage is not much greater on railways than canals;

2ndly. That railways offer such great advantages in point of speed as to compensate for increased cost of conveyance.

3rdly. That it is quite practicable to convey on railways bulky goods as building materials or minerals.

4thly. That if the profits derived by the conveyance of bulky goods are not very considerable, still the traffic can be absorbed, because a handsome profit is realised from the passenger traffic. (2)

5thly. Public opinion is in favour of railways.

6thly. All canal property has lost a great deal of its value since the opening of railroads.

1 This facility has not as yet been taken much advantage of on rivers and still less on canals, the passage of locks offers some difficulty; when horses are used, it is also difficult to haul more than one boat at a time.

2 See Perdonnet's "Traité pratique des chemins de fer."

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7thly. The continually increasing traffic on railroads proves that the public prefer that mode of conveyance for goods.

8thly. Canals are frozen, consequently impassable for a certain length of time every year.

The first argument, that of cheapness is not exact; up to a speed of about 4½ miles an hour, the resistance on canals is, as we have seen, inferior to that on railways. The cost of establishment, and that of repairs and management on canals are also inferior. (1) The use of condensing engines and coal fuel render the cost of the moving power less by water than on railways, so that a speed considerably above 4½ miles per hour may be attained at a cost still inferior to that of railways.

The second argument is granted; but only with certain materials. Builders and contractors frequently order building materials and minerals 3, 4, or 6 months beforehand, without any inconvenience, and they have the great advantage of loading and unloading when it suits them, whereas with railways, space being valuable, all goods must be removed at the shortest notice, or else heavy dues must be paid for leaving the goods at the station.

Among the articles for which canals seem eminently convenient are the following:

Bulky articles. Timber, bricks, stone, large castings.

Fragile do. Glass and pottery not packed in cases.

Articles of small value. Ore, minerals, ashes, manure, &c.

Timber is frequently conveyed in rafts; wood loses much of its strength after a long sojourn in water, but it becomes better for carpenter's work. Wine is said to be improved by a sea journey; when conveyed by land it frequently loses part of its good qualities. The railway is frequently preferred to sea or canal conveyance for coals, because in unloading vessels the coal gets broken, but this has been recently remedied by mechanical contrivances.

3rdly. It is very doubtful whether railways could furnish the sole medium for the conveyance of bulky articles. To do this, the goods trains must travel at the same rates as the passenger trains, (to the sacrifice of that important item of economy in the working of steam engines, expansion); if not, a 3rd line must be laid down at a vast cost for the sole transit of merchandise, or else the lives of the passengers must be daily jeopardised to an extent far greater than what we observe even at present.

4thly. M. Perdonnet says, that in many cases, as in that of the French Northern Railroad, those of Rouen, Strasbourg, and Orleans, that from London to Birmingham and from London to

1 Considerably inferior in England and on the continent. In the United States the canals have cost more than the railroads, the latter being very rough work.

Bristol, the profits derived from the conveyance of passengers and parcels suffice to pay the interest of the capital and the general expenses, so that the companies can content themselves with very small profits on the goods traffic. This is open to discussion, for it is very difficult to separate the passenger and goods account so completely as to tell exactly what are the profits relative to each.

5thly. Public opinion is no criterion. There are many reasons why railways should attract the public attention more than canals. The convenience in travelling; the wonderful speed; the *prestige* attached to the names of George and Robert Stephenson; the *mere noise* of the locomotive; have all tended to make the railway and locomotive popular.

The 6th argument cannot be denied; but too much importance must not be given to it. Suppose, instead of constructing railroads parallel to those canals which have most suffered as a property since their establishment we had established parallel lines of navigation, would not the result have been very similar.

As to the 7th argument, it is refuted by observing that in France and Belgium the traffic on canals has gone on increasing since the establishment of railways parallel to them.

8thly. The effects of frost can only be palliated; but I think they are not more inconvenient than a heavy fall of snow in a railway cutting, and are much less so than an interruption in the permanent way.

All these arguments, therefore, can only prove that canals have a severe struggle to keep up with railways. I will add, in favour of maintaining, extending, and improving our canal navigation, that the public, whose attention has been entirely absorbed by railways, has neglected the vast field for improvement offered by canals in general, and by those of England perhaps more than any. This will form the object of the next chapter.

Amalgamation with railway companies considered.

How the struggle between railway and canal companies is to end is difficult to say. I doubt whether the canal companies could appeal to the public to increase their capital so as to improve their means of conveyance, and better to compete with railway enterprise; the public is not in favour of canals, and shares would be raised with difficulty. A combination between the rival companies would put a stop to the struggle, but would establish a monopoly very unfavourable probably to the public interests. United action on the part of the canal proprietors will be beneficial, and a community of interests between the *canal owners* and *carriers* will be still more so.

Canals connected with irrigation—water works—drainage.

Attempts have been made to connect canals with irrigation of land, or with works for the supply of water, or with hydraulic machines for manufactures. The Canal de l'Ourcq, at Paris, serves both for the purposes of navigation and water supply. Som-

years ago a few boatmen let some tar fall, in considerable quantities into the canal, and the consequence was that the water could not be used by the inhabitants for a day or two; and as no one knew the cause of the accident, a long line of pipes was taken up before the real cause was ascertained.

As to irrigation and hydraulic machinery they may in some cases be made a considerable source of income to the canal owners; but more generally all the water is absorbed for the wants of the canal. Canals are very useful to agriculture in facilitating the drainage of land and in conveying manure, agricultural implements, &c.

CHAPTER IV.

IMPROVEMENTS SUGGESTED WITH REFERENCE TO CANAL ENGINEERING AND NAVIGATION.

Steam power to be applied.

The first step towards improvement is the application of steam-power to the exclusion of any other. The advantages offered by the use of steam are:

1st. *Economy.*—It is impossible to give any absolute estimate of the cost of conveyance with steamers and horses. The cost of steam-power in particular is very variable; but the following estimate will give an idea of the difference in the working expenses, exclusive of loading and unloading, and general expenses, which are nearly the same in each case.

Suppose it be required to convey 60 tons 100 miles.

A boat hauled by one horse will perform the distance in 48 hours.

	£	s.	d.
The horse driver at 6d. per mile will cost ...	2	10	0
Wages of crew, 2 days.....	1	0	0
Interest and wear and tear of boat	0	2	0
	3	12	0

Now, a steamer, with engines of 16 to 20 H. P., can convey 60 tons 100 miles in 20 hours. The cost will be about as follows:—

	£	s.	d.
Coal—2 tons at 15*s.*	1	10	0
Wages of crew, one day	1	0	0
Interest, and wear and tear of engines and boat	0	5	6
Oil, &c.	0	3	0
	2	8	6
Difference in favour of steam power, or nearly ·005*d.* per ton and per mile.	1	3	6

2ndly. The facility of increasing momentarily the moving power by reducing expansion and raising the pressure.

3rdly. That of conveying indefinitely large quantities of goods, according to the power of the engine, an object which cannot be attained with horses.

4thly. That of being perfectly self-dependent, whereas horses constantly occasion difficulties.

5thly. That of allowing the towing path to be suppressed, causing a very great saving of space in deep cuttings and tunnels, which may thus be made available in other ways.

6thly. Saving of time—any speed within 15 miles an hour is easily attainable, instead of 2 or $2\frac{1}{2}$, which is the pace of horses, but 4 or 5 miles an hour appear to be a good average.

Suppose a boat towed by horses to convey in one trip 60 tons to a given distance, and 30 tons back, the carrier will gain, say 20*s.* for the first trip, 10*s.* on the next; total 30 shillings.

The steamer will probably make two trips in the same time, conveying twice 60 tons to the same place, and twice 30 tons back. The boatman can make the same charge on each trip and gain £3. But he will probably content himself with £2., thus sharing with the public the benefits derived by the improvement and, in any case, a saving in time for the public will be effected; the number of boats forming the rolling stock will be diminished by half.

Towing and trains.

The next step is to introduce the *train system.* That towing is cheaper than carrying has been demonstrated more than once by actual experiment. (1) I have shown before that at a given speed, the length of the boat makes very little difference, the area of the immerged transverse section having the most influence on the resistance, so that with an indefinitely long vessel the cost of traction would be but little increased: as this is impracticable, we must obtain an approximation by the use of boats towed one astern of the other. This system has been long in use in America. The introduction of steam necessitates certain alterations

1 See Murray's Rudimentary Treatise on the Marine Engine.—Report on Canals in the Appendix.

in the dimensions of canals: First, the section of the canals and the dimension of the locks must be increased.

Alterations in dimensions of canals.

It has often been argued that large and deep canals offer more resistance than those with a small sectional area. Granting this to be true (and in our present state of knowledge of hydraulics, the fact has to be verified) we find that this argument in favor of maintaining the old dimensions loses much of its importance when we consider that all canals are frequented by boats drawing various depths of water: now, on the other hand, the power of increasing at any time the size and draft of water of boats is of great importance. Then as to steam-towing in particular, every one knows that steam-engines cost less, per H.P., the larger they are, and that no more men are required to work a two-hundred tons steamer than to work one of a hundred tons. Besides, steamers travelling much faster than boats tracked by horses would probably require a little more room for crossing each other without stopping the engines.

The widening of the pounds is not of so much importance as that of the locks, because the former can be done gradually and according to the wants of navigation, (where traffic is not very brisk the width should be calculated for a single boat with occasional sidings,) whereas the latter is an expense which cannot be divided. To be accessible to trains of boats, as on the Severn navigation, they should have the length of the longest train, and, at least, 3 pairs of gates, more if water is scarce, so as never to draw from the upper pounds more water than that strictly sufficient for navigation. It is needless to say then it takes no more water to pass two or more boats at a time than separately.

Increase of supply of water.

Supposing it to be granted that a wider sectional area and enlargement of locks are necessary, it becomes evident that the supply of water must be considerably increased, or else means must be found for diminishing the expenditure principally that due to lockage.(1) The first object can be attained

1st. By deepening the cuttings at the summit levels;

2ndly. By increasing the dimensions of reservoirs;(2)

3rdly. By *artesian borings* (Kind's system is the best) properly and carefully applied;

4thly. When these means fail to bring water to the requisite height in sufficient quantity, recourse must be had to machinery: the Cornish engine must be applied, it is in most cases the best.(3)

Substitutes for locks.

The second object, that of diminishing the expenditure of

1 See Chapter 1st, for evaluation of loss of water.

2 The depth particularly by means of dykes and weirs.

3 The works at the summit level of the Grand Junction Canal are well worth a visit.

water, can only be attained by two means; either suppressing locks altogether and having recourse to machinery, for raising or lowering boats from one level to another, or by restoring to each lock the quantity taken out of it for the passage of each boat.

Inclined planes (1) require machinery of the most expensive description, and can never work cheaply, because the machinery has to develop great efforts at a given time; generally, engines used intermittently give a bad result, because a great deal of steam is wasted and because they must be made on large dimensions. When the same work can be done gradually, a smaller engine answers the purpose. This is probably one of the reasons why locks have been maintained in preference to inclined planes, even in cases where it has been found necessary to raise water for lockage at a height varying from 50 to 70 feet, as in the case of the Ering summit level. If I were to advocate any mechanical mode of raising boats from one level to another, I would suggest the hydraulic press.

Side reservoirs and double locks.

If a reservoir A, or a second lock, be made next to the one in use B (Fig. 19) with a sluice, at S, to open or shut off its communication with B, it will enable one to save $\frac{1}{2}$ a lockful; for, supposing $\overline{mn}$ and $\overline{op}$ to be the level of the water in the upper and lower pound, if we want a boat, say, to go down, we shall open the sluice at S and turn out the water remaining in the lock into the lower pound; we shall thus have $\frac{1}{2}$ lockful ready for an ascending boat.

Andraud's vacuum lock.

I now come to a recent invention of a French Engineer, M. Andraud, for restituting the water momentarily abstracted from the lock for the passage of each boat. With M. Andraud's invention, we save the entire lockful, instead of $\frac{1}{2}$ as in the preceding case; for, reservoir A, instead of being open, is shut in and air tight, and communicates with an air pump which rarefies the air in A till all the prism of water in *n. o. p.* is introduced into A (see Fig. 20). To the air pump may be substituted a small coal fire; I believe it is this system which was originally proposed by the inventor. This seems a really practical invention.

Time lost in locks.

An important object of consideration is the loss of time in passing from one lock to another. Wherever the supply of water is sufficient, let locks be made as deep as possible (2) so as to reduce to a minimum the number of locks necessary for a given total fall. I see no reason for giving the lower locks the same dimensions as the upper ones; let them be larger if

1 In some cases the boats descending inclined planes have been made to draw up the empty ones. This cannot be applied if the ascending boat is laden, besides it must wait for the descending one.

2 The expenditure of water is at a minimum when the fall equals the depth of the boat's draught of water.

they can easily be supplied with water. Signals should be used to warn the lockmen at the approach of boats; double locks should be preferred although they cost more; the openings for admitting water should be larger.

Importance of river navigation. Lateral canals not always useful.

If it is allowed that a large sectional area is necessary, then, it becomes evident that too much importance cannot be given to river navigation. I must doubt whether it was a right step to establish several miles of canal parallel to rivers, as the Kennet and Avon Canal parallel to the Kennet; the Rhône au Rhin Canal parallel to two rivers (the Rhine and the Ill) &c. instead of improving the bed of the rivers themselves and simply shortening the distances by cuts avoiding the bends. It will be urged that the establishment of locks and weirs in some rivers would be very difficult; then let our endeavours, by all means, be directed towards improving this branch of hydraulic engineering.

There is no doubt that foundations in a large river, with strong current, are very expensive, but this part of the Engineer's art has much improved since Brindley and Brisson. Persons interested in this branch of construction would do well to read the accounts of the Chester and Rochester bridges, the French and German works on the process known as "*Fondation sur encaissement.*"

Expense of alterations.

It will be asked what would be the expense of widening our canals, and applying some of the alterations proposed. That is impossible to say: but the alterations can be made gradually; and we can assign a limit to the expenditure. We can expend as much on the establishment of a canal line as is spent on the nearest parallel railway, and have nothing to fear from the latter, as the cost of conveyance, exclusive of general expense, is less on the canal than on the railway.

Transfer of goods to be avoided.

The object of canal or boat proprietors should not be to adapt the form and dimensions of boats to those of canals or *vice versa*, but rather to adapt both to a direct communication with rivers, harbours and estuaries, in such a manner as to suppress, or, at least, to reduce to a minimum all transfer of goods, avoiding thereby destruction of property, expense of loading and unloading, wharfage, agency and loss of time. This object cannot be attained by the canal owners alone, but needs the co-operation of the inland and maritime conveyance companies, such as the Thames Steam Tug Company, the "M.M. Pieau et C^ie.;" "Souberbielle et C^ie.," (1) and others.

Ship canals.

This leads me naturally to say a word about ship canals. The mere inspection of a map will at once give an idea of the localities most favorable to works of such magnitude. In

1. See Appendix, note on Navigation on the Continent.

chapter first I have explained that, in topographical maps, when horizontal curves are hollow, they indicate a depression in the same way where the coast line recedes, inwards, there is also a depression, as at the Isthmus of Suez, the Caledonian Canal, &c. Might not a line be found favorable for a direct ship-navigation from Galway or Limerick to the German Ocean, thus avoiding the Channel? The Forth and Clyde estuaries have already been suggested by Mr. Macpharlane; a line from Newcastle to Carlisle, or from Hull to Liverpool, is perhaps feasible; it is proposed to make one from Southampton to the Thames. Ship canals are most frequently supplied from the sea itself: in that case the total fall is limited by the height of the spring tides.

Steamboats—Engines and propellers.

The annexed table, reducing to three types all the systems of machinery at present in use on screw-steamers, will, I think, enable non-professional persons to choose the best kind of engine according to circumstances. M. Inshaw, of Birmingham, has built, for the Grand and Regent's canal, boats with two screws astern, one on each side of the rudder, revolving in opposite directions and worked simultaneously by the same engine; these boats are said to be very good and to steer well when going stern on. In Plate 2 are sketches indicating:

1st. A description of boat which I propose for river and canal navigation; owing to the peculiar shape of the cross section of this boat, fine lines can be obtained underneath without much loss of space. The deck is scarcely tapered at the end, so as to give room for loading and unloading.

2ndly. A disposition of machinery, which I consider would be applicable to boats with two screws. In the ordinary boat with two screws, the engine acts on the screw shafts, by means of bevelled gear, so that, if the latter breaks down, which is a frequent occurrence, the engine is of no use. In my sketch, the engines work directly on the screw shafts, a strap connects the 2 screws, but only to ensure regularity in working; if it breaks, the only effect will be that the engines will work separately.

Experience alone can show the best dimensions of boats and locks; if 90-ft. by 15-ft. were found to answer, it would save the necessity of rebuilding on larger dimensions a vast number of our locks; still, when a lock is much out of repairs, I would advise rebuilding on larger dimensions.

Better to maintain a few large canals than a great many small ones.

I have observed before in Chapter 2d, that canals are different from roads in not being universal. That they are dependent on certain conditions of geology and physical geography. With such powerful means of conveyance as those offered by railways, on one hand, and coasting vessels (screw vessels in particular) on the other, we should be wrong in laying out large sums of money to maintain certain lines of navigation which do not present certain natural resources, and which do not allow, from

the unfavourable circumstances in which they are placed, of conveying large quantities in a given time. I am convinced that the future prospects of inland navigation lie in improvement of our rivers, widening of our canals, and application of steam power to towing trains of boats. Except in a few rare cases, we cannot afford to maintain narrow canals; if it be too expensive to widen them, let them be turned to account as feeders to the wide canals, or for water-works or agriculture, and the wide canals should be in immediate connexion with our sea-ports and docks.

This was exposed before I met with the following passage in one of the most remarkable works ever written: *Flachat's Projet de canal maritime de Paris au Hâvre:*

"Goods can be conveyed by sea more economically than by "inland navigation. . . . . It follows that, even at "greater distances, sea-ports enjoy more means of exchange of "produce between each other than towns in the interior, since "they can communicate at less expense. . . . . "... —. Thus it is that the greatest commercial activity "prevails in sea-ports, for trade extends according to the means "of communication. Therefore it is evident that, for the greatest "good of the country, sea-ports should enjoy the most ample "means possible of putting the interior in possession of those "commodities which can so easily be exchanged from one sea-"port to another. We can therefore establish as a principle, "that a proper system of navigation ought to converge from the "interior to the principal ports of the sea coast and that it is "easy to foresee that the most important lines of navigation will "be those which join the most flourishing sea-ports to the towns "where the manufactures are most important or the consumption "greatest."

CHAPTER V.

Parliamentary powers of canals in what they are defective.

Government has done little in England towards the execution of canals.

On the Continent canals belong with very few exceptions to government; they are open to all kinds of boats, upon payment of a small toll proportional to the distance ran and to the volume

or weight of goods conveyed. The works are executed and maintained by Government Engineers, and the tolls are levied by agents depending on the Minister of Finances.

It is needless to say that this only forms part of a vast fiscal system tending to make the wants of the public an object for speculation on the part of government, and to secure a monopoly to the latter. In some cases, canals are the property of companies; but their grant of concession is limited and they are redeemable by government, after a certain number of years.

In England, neither of these systems is followed out: the Caledonian canal is, I believe, the only British canal undertaken by government. As a speculation it is a failure, but as a work of national importance it is a very remarkable one, and perhaps justifies the expenditure which it has been the cause of.

They belong mostly to Joint-stock companies. Act of Parliament necessary.

Most of our canals and navigable cuts belong to Joint-stock companies, incorporated by Act of Parliament, and are not redeemable by government; each of them has formed the object of a separate act.

The following acts and many others are worth of an attentive study:

(1) Aire and Calder Navigation.....	10 & 11 Will. III.	c.	19	1699.
	1 George IV.	c.	39	1820.
	14 George III.	c.	96	1774.
	9 George IV.	c.	98	1828.
(2) Croydon Canal	41 Geo. III.	c.	127	1801.
(3) Forth and Clyde ...	8 Geo. III.	c.	63	1768.
	46 Do.	c.	120	1806.
(4) Grand Junction	33 Geo. III.	c.	80	1793.
(5) Regent's	52 Geo. III.	c.	195	1812.

The act 33 Geo. III. cap. 80 contains, among others, the following provisions relative to the Grand Junction canal:

Counties and parishes through which the line is to pass;

Dimensions of canal;

Plans and book of reference. No deviation of more than hundred yards from the plans and book of reference to be made without the consent of land-owners;

Provisions of a purely legal character;

Commissioners appointed to adjust difference between the land-owners and the proprietors of the canal—their qualifications;

If parties are dissatisfied with the award of the commissioners, value to be ascertained by a jury, and verdict to be final;

Power given to the company to enter and take possession of land on payment;

Expenses of witnesses defrayed;

The proprietors can be obliged to purchase small pieces of land separated in making the canal;

Questions of local or private interest;

Amount of capital to be raised;

Sale of shares;

General assemblies enforced;

Rates of tonnage (maximum), regulations concerning boatmen, of boats.

To execute a canal, railway or other work of public utility, it is necessary:

To present a petition through a member of the House of Parliament;

A bill is then read, three successive times, in each House, during which time special committees are formed for discussing the subject and witnesses examined; the evidence being gone through in both Houses;

An Act is then framed and receives the Royal assent;

Surveys and book of reference are prepared in the meanwhile, and submitted to the commissioners appointed by the act;

The proceedings cannot be carried on without legal advice;

All deeds are to be registered and are subject to the ordinary fees and stamp duties; the discussion of questions of public utility can nowhere be more thoroughly investigated than in the Houses of Parliament; but the examination of witnesses, who must be defrayed at the Company's expense is sometimes enormous; the absurd practice of going through the evidence of both Houses is expensive, useless and tedious.

Acts concerning the execution of public works should never contain restrictions of a purely private character.

The two great desiderata are, I think,

1st. General regulation applicable to all railway, canal, or dock companies, for such proceedings as are common to all works of that nature, but particularly for the purchase of land and compensation.

2ndly. A special court, constituted once for all, to settle all disputes relative to such works; the said court being authorized by both Houses of Parliament and consisting of engineers and lawyers.

Parliamentary discussions on public works are unknown on most parts of the continent. The object attained in England by committees is attained there by public inquests (enquêtes). That is; a copy of the plans and book of reference is deposited in the "Mairie" of each parish, after preliminary advertisements, and

remain there a week or more; every one being allowed to inspect them free of charge; those persons who have objections to make, enter them into a book left on the table for that purpose, signing their names and stating their motives of objection. This book is then sent to the civil authorities who decide whether the plans are to be adhered to or altered. The following is the manner of proceeding in France:

Petition to Minister of Public works;

Preliminary inquest, recognising the works to be of public utility;

Convention with Minister of Public works, regulating the amount of capital, subsidy from Government scale of charges of the company; reduction of tariff and dividend on profit in favor of Government &c.;

Imperial decree ratifying the convention;

Surveys and book of reference and final inquest;

Jury for compensation;

Payment through the hands of a notary.

Registration is compulsory, but no charge is made; unless great opposition is met with, an engineer and notary can go through all the formalities at a very small expense, without employing a solicitor, in the space of a few months, but the works may be begun in the meanwhile.

CHAPTER VI.

§ 1. On management of canals.

The management of canals comprises the various methods of executing works for canal lines, extensions or repairs and of working the canal.

The works may be done under the owner's immediate responsibility, or by contract, or by valuation.

Best manner of proceeding with works.

The first system can only be had recourse to for works of little importance and when despatch is not necessary, or when the cost cannot be approximatively determined.

The contract system offers one advantage; rapidity of execution. It is seldom possible to estimate the *quantities* with much

precision; the consequence is that a high price is asked to meet all casualties; if none present themselves, the contractors reap a large fortune, at the owner's expense; if unforeseen expenses occur, losses are made up for, by giving bad work and bad materials; the following circumstances can alone justify such a system:

1st. Necessity of proceeding with great rapidity; 2ndly. The well known morality of the contractors; 3rdly. The possibility of computing the expenditure with some degree of precision.

The best way of proceeding is, *first* to draw up a list of prices and pay the builders according to valuation; the advantages are, that better workmanship and better materials are obtained; the builders can content themselves with a moderate profit because they run no risks; when the works give dissatisfaction, they can be stopped and agreements made with other parties; and the owners are free to change their plans at any time; or, *secondly*, to combine the two systems, contract, for that which is certain, a schedule of prices, for what is uncertain.

Best manner of working a canal.

The question of working expenses is more important in the present position of our canals. A canal may be worked in three different manners:

1st. It may be left open to all boats, on payment of a toll;

2ndly. Or, the owners may find boats, steamers, horses, &c., and work them or a part of them, at their own cost and risk;

3rdly. Or, they may make an agreement with a contractor for all or part of the traffic of the line.

The first system cannot very well be applied *exclusively*, at least, by private individuals or companies; such a source of income would fluctuate too much in a great many cases. When the owners are equally interested in the canal, as a property, and in the traffic, as a source of income, the canal is worked with more advantage, and the boats and canal are better adapted to each other, than when the interests are entirely separate. The contract system may be applied here with advantage. One can ascertain pretty accurately the expense of keeping a horse and driver, of working a steamer of a given horse power, etc., so that the owners can throw all responsibility on the contractors. Besides, no contract need be made for more than one or two years; so that, when the contractor does not give satisfaction, he can be dismissed. This system is largely used for the working of locomotives on railways; it simplifies the company's accounts and reduces the staff of *employés* under their superintendance.

On rivers, steam tugs are furnished and paid by time, or according to tonnage and distance ran; as on canals, boats of all kinds cannot be admitted, it seems best that the owners of the canal should work their own boats.

On charges for conveyance.

The tariff should be as simple as possible: 2 or 3 classes are quite sufficient to comprise all objects of traffic.

On a much frequented line, and where bulky materials are conveyed, the working expenses are greater, on a narrow canal, than on a broad one; only, when traffic is but limited and consists chiefly in the conveyance of objects of small dimensions, the working expenses are less, when small boats are used, because they run less risk, than large ones, of returning without a cargo, and the dead weight conveyed is thus less.

Amalgamation with railway and maritime conveyance companies considered.

I have already suggested the probable advantage of a combination of railway and canal companies, observing at the same time that such a combination might be injurious to the public interests. I would prefer seeing a combination made with steam-tug or maritime conveyance companies, as inland navigation is only the complement of maritime conveyance, and a community of interests between them would probably be the cause of improvements useful to the public.

Best way of carrying out improvements.

Supposing some of the improvements I have suggested in Chapter 4th to be carried out, it becomes a question how and where they are to be applied. A general increase of expenditure all along a canal would perhaps be rather hazardous. I propose widening and improving our canals;

1st, in localities where a considerable traffic exists or may be expected, and in particular on lines perpendicular rather than parallel to railways;

2ndly, in the vicinity of harbours, docks and navigable rivers, effecting as easy a communication with and between them as possible;

3rdly, enlarging the pounds only where it can be done at a moderate expense, in other places leaving only room at present for the passage of boats one way, with occasional sidings, till an increase of traffic justifies further expenses;

4thly, rebuilding locks on larger dimensions, only when they get out of repair;

5thly, buying property for extensions as soon as possible, particularly where it can be done without compulsion, but without extending the works till the wants of an increased conveyance make it necessary. In the meanwhile the ground may be let or otherwise made available.

§ 2. On accounts and statistical information.

Classification of receipts and expenses.

The following will give, I believe a correct idea of the receipts and expenditure of a canal company, a few items varying of course according to the manner in which the company is constituted. (1)

1 The *cooking* of accounts is carried on on a small scale more frequently perhaps than is generally supposed. This often arises by the directors putting absurd restrictions on the expenditure. Expenses of little importance, but

RECEIPTS.

A.

1. *Capital account.* Payment of shares, interest of shares in arrear, interest of money lent or invested by the company.

2. *Property.* Sale of landed property or buildings, sale of produce of grounds planted or sown by the company; sale of right of fishing, &c.

B.

Annual revenue account. Receipts for conveyance by boats belonging to the company according to classification of goods; lease of ground or other property; tolls levied on boats not belonging to the company; carriage of goods in towns; miscellaneous; balance brought over from preceding years.

EXPENSES.

C.

Cost of establishment. Expenditure of central office, salary of directors &c., interest of shares to be paid till the works are completed; banker's commission, stamps, letters, advertisements, &c.; parliamentary expenses, surveys; law expenses; salaries of engineers and surveyors; buying of property; lease of property for temporary works; earthworks; tunnels, locks, bridges and masonry; docks and basins; deviation of roads or watercourses; compensations for do.; workmen employed under the company's immediate direction; miscellaneous.

D.

Establishment of boat and rolling stock. Acquisition of boats; do. of horses; of steamers; miscellaneous.

E.

Annual expenditure.

Central office and general expenses. Salary of clerks &c.; office expenditure, (firing, stationery, &c.) advertisements; law expenses; taxes and insurance; dividend on shares.

Repairs and maintenance. Salary of clerks, surveyors and toll collectors; wages of lock-keepers, repairs of locks—extensions and alterations of small importance; warehouses and wharfs; miscellaneous; repairs of roads and towing paths.

Working expenses. Repairs of boats; coke and coal for steamers, miscellaneous articles for do. and engines; wages of boatmen; maintenance of horses; miscellaneous.

contrary to the Co.'s orders, are incurred sometimes unavoidably; the accountant refuses to enter them, and as no one will make up the deficiency out of his own pocket, the expenses are accounted for by means of fraudulent entries.

Special acts of parliament regulate the control of all joint stock companies' accounts, enforcing periodical meetings of shareholders.

There is in Great Britain a great dearth of statistical informations on commerce and industry and particularly on canals—it is always so, where there is a liberal form of government—statistics, centralization, I might perhaps add despotism, seem to go together. The fact is that companies will not publish their accounts unless they are obliged. But there is a great deal of information which canal companies could and ought to publish; nothing is more likely to secure the confidence of the commercial public in any undertaking than a regular publication of accounts.

Traffic returns should be made every 6 months and compared with those of railways; the increase and decrease should be noted; the causes of both carefully ascertained. These returns can be expressed very conveniently by diagrams. Every opportunity should be siezed of obtaining informations on the canals in Sweden, Russia, Belgium, France, Holland, Canada, and the United States. Our canals are totally different from them.

We know very little of the laws of hydrodynamics relating to the resistance which fluids oppose to the movement of boats or floating bodies; how that resistance varies with the shape of the boats, with their length, their breadth and, in cases where several boats are towed together, with their number and the distance which separates them; also how the resistance varies with the breadth and depth of the canal or medium in which the boats move. In my opinion it is most important that these questions should be solved as soon as possible, by means of experiments repeated both on a large scale and on small models. (1)

CONCLUDING REMARK.

I think the public generally do not sufficiently appreciate, nor sufficiently pay the advantages of roads, canals and railways. We find railway fares too high for the accommodation offered, and have no regard for the original shareholders; we find the canal boat too slow; object to the turnpike system although it offers the most equitable mode of assessing a tax for the maintenance of roads; and if a new line of railway or canal passes through our property, we feel ourselves in duty bound to charge more to the owners than we would demand of a private individual. It must be recollected that in England, at least, these institutions get no support from government.

1 I hope to be able to resume soon the experiments which I began last year with this object, but which I was obliged to abandon for want of time and of proper instruments.

HISTORICAL AND DESCRIPTIVE TABLE

of some of the most important Canals executed up to the present time.

Country.	Designation of Canal.	Promoters or Owners.	Engineer.	Length in miles.	Width at the surface of the water.	Depth.	Maximum tonnage of boats.	Total cost.	When authorized.	When opened all through.	Observations.
					Ft.	Ft.	Tons	£			
Belgium	Brussels to Wilbrock	Town of Brussels ...	Rinialdi	19	98	8	100	?	1550	1568	
France	C. du Midi, or du Languedoc	Riquet	Riquet	190		5	120	680,000	1666	1681	
England	Trent and Mersey	Company	Brindley	60	22	4½	60	334,000	1699	1790	
Do.	Leeds and Liverpool	Do.	Do.	130		7	60	1,200,000	1720	1816	
France	St. Quentin	Government	De Regemorte—Gayant—Brisson .	60	45	6.6	250	480,000(?)	1724	1810	
Russia...	Ladoga				40 average.	from 3 to 7			1730		
England	Bridgewater..	Earl of Bridgewater	Brindley	40			120	220,000	1737	1776	
Do.	Staffordshire & Worcestershire	Company	Do.	47			25	112,000	1766	1802	
Scotland	Forth and Clyde	Do.	Smeaton	35		10	160	519,840	1768	1790	
England	Oxford	Do.	Brindley	91	28	5	25	5,202,300	1769	1790	
France	Rhône au Rhin	Government		203	43-49	5	140	1,080,000	1783	1834	
England	Grand Junction	Company	Jessop & Brindley	90	40	5	25	1,150,000	1793	1803	
Do.	Kennet and Avon	Do.	Rennie	55	44	5	70	1,272,000	1794	1810	
Do.	Paddington	Do.		14	43	5	60	283,700	1795	1802	
France	St. Denis	Town of Paris	Brisson	9	75	6.6	500	97,000	1802	1810	
Belgium	Brussels to Charleroi	Government		46	43	6	100		1803	1831	
Scotland	Caledonian	Do.	Telford—Jessop—Watt	60	110	20		921,373	1803	1822	
Belgium	Mons à Condé	Do.		49	115	6			1807	1825	
France	St. Martin	Town of Paris	Brisson						1808	1825	
U. S. ...	Erie	The States	Wright—White—Robert	363	70	17	130		1817		
Holland	North Holland (Ship C.)	Government		49	115	17			1819		
Canada	Rideau										Want of time has prevented me from obtaining information on this stupendous work.

APPENDIX.

Prices of Canal Shares.

DESIGNATION.	Original value of Shares.	PRICES OF SHARES.		
		Before opening of Railway.	In October, 1844.	In December, 1856.
Birmingham	79	215	165	91½
Derby	100	138	105	84
Kennet and Avon	40	26	10½	6¼
Leicester	140	200	139	49¼
Oxford	100	610	505	103
Peak Forest	78	91	40	76
Stafford and Worcestershire	100	650	480	440
Worcester and Birmingham	100	89	50	20
Regent's	33	16	25	16⅛
Grand Junction	100	235	162	
Leeds and Liverpool	100	760	640	

Relative resistances on Turnpike roads, Railways and Canals.

Rate of speed in miles per hour.	RESISTANCE IN POUNDS PER TON.			Ratio of resistance on roads and canals.	Ratio of resistance on canals and railways.
	Turnpike roads.	Canals.	Railways.		
2½	73	2·73	8·50	26·7 : 1	·32 : 1
4	73	7·07	8·50	10·3 : 1	0·83 : 1
8¾		36·80	8·50		4·33 : 1
9	83		8·50		
10⅜		57·30	8·50		6·74 : 1

Tolls paid on the Canal from the Rhône to the Rhine, since its opening.

	f.	*c.*	
In 1834	293,586	15	
1837	655,697	82	
1839	802,965	51	
1841	766,382	69	(Railway opened from Paris to Strasbourg.)
1845	855,592	95	
1847	1,107,109	56	(Freight reduced on railway.)
1850	982,159	75	(Tolls reduced on canal.)
1851	1,016,529	80	
1853	1,354,869	56	
do.	64,748	35	(tolls applicable to boats laden with corn, but not collected on account of the scarcity of food).

Tolls paid on the St. Quentin Canal,

forming part of the line of navigation from Paris to Mons and Valenciennes.

	f.	c.	
In 1827	132,903	93	
1835	780,845	53	
1840	1,065,646	64	
1845	1,892,655	93	
1847	2,116,914	71	
1848	1,498,375	27	
1849	(?)		(Railway opened to Valenciennes.)
1850	959,123	97	(Tolls reduced.)
1851	1,021,186	32	
1852	1,063,948	36	
1853	1,153,187	40	(19,533f. 13c. not collected for corn.)

N.B. The receipts on the Rhône and Rhine canal have considerably increased since 1853, but I have not the figures. As yet it appears to have been a bad speculation or to have been mismanaged, since the first outlay was 28,249,562 fr.

I have not the traffic returns of the St. Quentin Canal for 1855, 1856, and 1857. The receipts will probably decrease for a short time on account of the new direct line from Paris to Erquilines and Charleroi. But the introduction of steam navigation, a better construction of boats, the deepening of the canal to 6-ft. 6, and a revision of the tolls which the Government can very well afford to reduce, will soon enable the carriers to compete successfully with the railway for the conveyance of coal, &c. and a great increase of traffic may be expected in a year or two. The first outlay on this canal was about 12,000,000 fr.; it has been of great service to some of the manufacturing districts of the north of France. The following is an

Extract of Traffic returns of the St. Quentin C.

Tonnage reduced to 1 Kilomètre (0.62 miles).

	1851.		1852.		1853.	
	Cambrai to Chauny.	Chauny to Cambrai.	Cambrai to Chauny.	Chauny to Cambrai.	Cambrai to Chauny.	Chauny to Cambrai.
	t.	t.	t.	t.	t.	t.
Corn, Fruit, Vegetables	32,500	6,754,000	63,200	7,343,800	408,000	6,229,000
Coal and Coke	65,335,600	479,700	68,862,000	844,300	75,465,500	897,000
Miscellaneous	6,494,300	8,031,100	6,581,000	7,885,300	7,404,400	9,673,300
(*The tonnage is in round numbers.*)	71,862,400	15,264,800	75,506,200	16,073,400	83,277,900	16,799,300
	87,127,200		91,579,600		100,077,200	

Returns shewing the relative importance of the Coal traffic on the "Chemin de fer du Nord," and the Northern navigation by the Escaut and Canal of St. Quentin.

Belgian coals imported by the Escaut since the opening of the railway to Luiévrain in 1846.

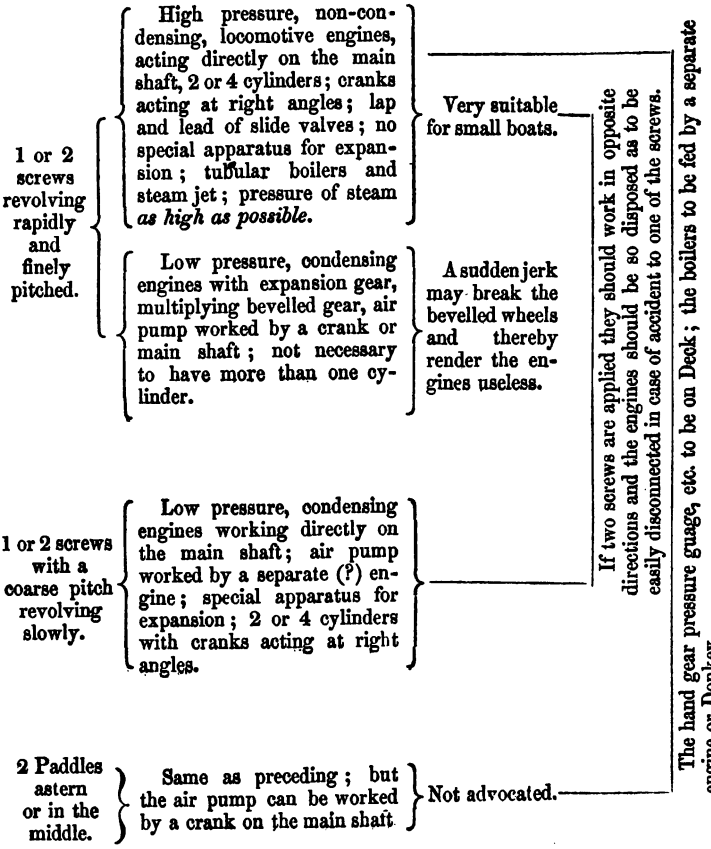
In 1846	801,505 tons.	From the report of the half-yearly meeting of shareholders of the Northern railway, April 30th, 1852.
1847	961,463	
1848	772,135	
1850	1,015,579	
1851	1,033,118	
1852	1,048,670	
1854		

Coal and coke conveyed per Northern railway, *including the produce of the mines of Valenciennes and Angin.*

In 1851	110,000 tons.
1852	181,142.
1853	"
1854	594,000.

These few figures shew the importance which traffic may acquire on a navigable line accessible to large boats; but it must not be denied that the railway company's profits are much larger in proportion than those of the canal carriers; so that if they do not wish to see the tables turned they must introduce a thorough reform in the mode of building and working their boats; vessels of 150 to 200 tons, square at both ends, and tracked by horses, are used almost exclusively.

Different systems of Steam Engines and Propellers.


1 or 2 screws revolving rapidly and finely pitched.
High pressure, non-condensing, locomotive engines, acting directly on the main shaft, 2 or 4 cylinders; cranks acting at right angles; lap and lead of slide valves; no special apparatus for expansion; tubular boilers and steam jet; pressure of steam as high as possible.
Very suitable for small boats.
Low pressure, condensing engines with expansion gear, multiplying bevelled gear, air pump worked by a crank or main shaft; not necessary to have more than one cylinder.
A sudden jerk may break the bevelled wheels and thereby render the engines useless.
1 or 2 screws with a coarse pitch revolving slowly.
Low pressure, condensing engines working directly on the main shaft; air pump worked by a separate (?) engine; special apparatus for expansion; 2 or 4 cylinders with cranks acting at right angles.
2 Paddles astern or in the middle.
Same as preceding; but the air pump can be worked by a crank on the main shaft.
Not advocated.
If two screws are applied they should work in opposite directions and the engines should be so disposed as to be easily disconnected in case of accident to one of the screws.
The hand gear pressure guage, etc. to be on Deck; the boilers to be fed by a separate engine or Donkey.

Notes on Inland Navigation on the Continent.

FRANCE.

Notwithstanding the numerous railways which are fast spreading over the country, and the handsome and commodious vessels which ply between the seaports on the coast of France (vessels built on eminently scientific principles, costing from 200 to 500 francs per ton, and conveying freight at very low rates), the traffic on canals and navigable rivers in France has been continually gaining in importance.

Competition seems to have excited the ingenuity of the Engineers, as will be seen by some of the following innovations:—

Verpilieux's steamers.

Verpilieux's paddle-boats are adapted to stemming the Rhône and other strong currents. The paddles are armed at the periphery with strong iron claws, like the flukes of an anchor, and can be raised or lowered without ceasing to be propelled by the engines. When raised, they act in the ordinary manner; when lowered, the claws strike the bottom, and a resisting fulcrum being obtained, the most rapid current may be stemmed.

The hydraulic car (fig. 24).

Imagine an ordinary locomotive, with this exception, that the driving wheels are propelled by water power instead of steam, the permanent way being composed of a railway and canal together; you will have an idea of the hydraulic car. It may be useful in turning torrents to account for the conveyance of minerals or timber.

Barrages mobiles.

These are simply moveable weirs of a more or less ingenious construction. They serve to regulate the regime of a river, and to afford a downward passage to rafts of wood; the passing of such a place is not always void of danger. A description of Mr. Poirées' barrages ought to be read.

Bateau toneur.

The "bateau Toneur" used on the lower Seine and the Oise (fig. 23), is moved by means of a revolving drum on which passes a chain extending all along the bottom. It is used as a tug-boat.

Fourneyron's sluice and lock-gate.

Fig. 21 shows an ingenious and completely *practical* invention which the eminent hydraulic engineer, Mr. Fourneyron, proposed some years ago for the weir and lock at the "Monnaie," Paris. Each gate is articulated at 1, 2, 3. A conduit reigns through the side wall, and connects the water above, below and behind the gate. If S be opened and S_2 closed, the water from the upper level fills the conduit, finds its own level behind the gate, and pressing on the panels $\overline{12}$, and $\overline{23}$, closes the gate. If we want to open the gate, we shall close S, and open S_2, as in fig. 22; the water will run out into the lower level; the pressure above the gate will then be less than the pressure behind it, and it will collapse against the side wall.

The two sluices S, S_2, are worked by the same lever, and are made to turn on a pivot, so that scarcely any effort is necessary to open or shut them. This invention has been found by repeated experiments to be perfectly applicable to rivers and canals, whatever may be the difference of level.

The Seine steamers.

Several descriptions of iron steamers, but all of a superior make, now run from Paris to Rouen, Hâvre, and London. They load and unload in Paris, at the "Cassin de la Vilette," passing by the canal St. Denis. They carry from 150 to 250 tons of freight, and have engines and propellers astern. (1) The propellers are 2 paddles, one on each side of the sternpost, or 1 screw before the rudder, or 2 screws revolving in opposite directions.

The Express boats are fine sea-going vessels, with 2 screws, and taffrail

1 The canal Saint Denis may almost rank as a ship canal.

before the funnel. The "Paris et Londres" are auxiliary screw schooners, conveying cargo in one bottom from Paris to London in 5 days, including stoppages at Rouen and Hâvre.

Most of these vessels are propelled by condensing engines.

Steamers ply on most of the French canals, but steam-haulage is seldom applied except on rivers.

SWEDEN.

The following is a hasty note communicated to me by a friend, H. Parish, Esq. of New York:—

"My opinion is that the application of steam to canal navigation has been more successfully carried out in Sweden than elsewhere; the steamers are all screw steamers, and travel at the rate of 9 to 10 miles an hour, excepting where the canal is narrow, and they are obliged to go at half speed to avoid washing the banks; the engines (fig. 25) are small and compact; the cylinders are inclined, and rest upon a hollow bed-plate, which is the condenser; the air-pump and feed-pump are worked either by eccentrics on the main shaft, or directly from the cross-head of the piston-rod. The hand-gear is on deck. This engine is almost universal in Sweden, and is well known, having obtained a medal at the French Great Exhibition. The vessels convey from 150 to 200 tons freight, and could tow several barges."

William Carter, Printer, Hammersmith.

ERRATA.

Page 18, line 28 *for* "restituting," *read* "restoring."
„ 20, line 44 *for* "on one hand," *read* "on the one hand."
„ 21, line 11 *for* "exposed," *read* "written."
„ 22, line 19 *for* "worth of," *read* "worth."
„ 23, line 28 *for* "defrayed," *read* "remunerated."
„ 23, line 29 *for* "evidence of both," *read* "evidence in both."
„ 24, line 3 *for* "enter them into," *read* "enter them in."
„ 24, line 4 *for* "motives of objection," *read* "reasons for objecting."
„ 24, line 26 *for* "On management of canals," *read* "On the management of canals."

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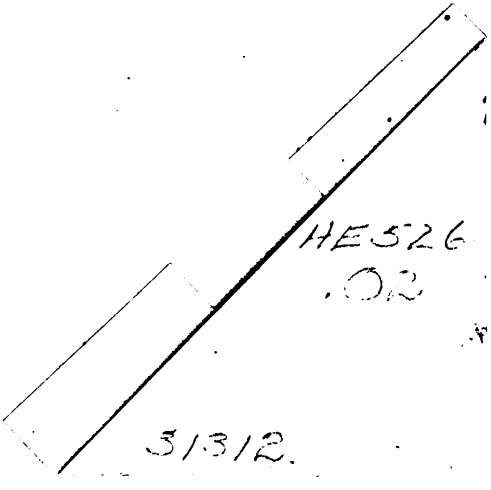
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